Debunking the Myth of Open Burning/Open Detonation's Environmental Unacceptability

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INTRODUCTION

For more than 40 years, open burning/open detonation (OB/OD) procedures have been the mainstay of energetic-ordnance disposal activities. Because these thermal treatment processes have been safe, reliable, expeditious, and economical, both government and industry felt little incentive until the early 1980s to develop other means for destroying the preponderance of unwanted munitions. In the last decade, however, OB/OD operations have been under a cloud of environmental suspicion, and provisions of the Resource Conservation and Recovery Act subpart X sparked widespread concern that many or most OB/OD sites would be closed by the end of 1991. The ammunition community continues to bear these concerns.

Although most OB/OD sites remain operational, the demilitarization situation is serious. The amount of munitions awaiting disposal, 250,000 tons ten years ago, will reach 425,000 tons by the end of CY94[1]. As overseas stocks return to the continental United States and as combat units deactivate, this burdensome inventory will continue to grow. The storage system, already saturated, will be less able to accept and properly store these munitions as military installations, including storage depots, are being realigned or closed. And, both environmental regulators and the public are showing increased interest in disposal activities, particularly OB/OD operations. If regulators were to decide to close all OB/OD sites because they believed these thermal treatments unsound, our serious situation would become critical.

OPTIONS

Some options exist for reducing the demilitarization inventory. The more important are selling or giving the materiel away, incinerating unwanted items, employing alternate technologies, or defining the environmental consequences of OB/OD operations to see if OB/OD-generated emissions actually constitute a problem.

FOREIGN MILITARY SALES

Foreign military sales have the advantage of producing revenue, assisting our allies, and

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reducing our inventories of excess items. However, foreign nations frequently are not interested in acquiring obsolete, damaged, or otherwise depreciated munitions, or munitions that are incompatible with their weapons systems.

INCINERATION

Incinerators are in use at many locations. However, they are commonly restricted in the types of munitions they can destroy and have limits on the net explosive weight (NEW) that they can accommodate. An additional complication is that regulators are showing increasing reluctance to permit incinerators.

ALTERNATE TECHNOLOGIES

Alternate technologies offer the capability of destroying munitions without releasing emissions into the atmosphere. The technologies, however, are difficult and individual research and development efforts sometimes expensive and prolonged. Developing alternate technologies for all energetic munitions in the demilitarization inventory may be fiscally challenging in an era of increasingly austere defense budgets.

DEFINE ENVIRONMENTAL CONSEQUENCES OF OB/OD OPERATIONS

Before issuing permits, regulators want evidence that proposed OB/OD operations will not injure the environment. In the early 1980s, no-one had successfully characterized emissions produced by OB/OD operations. If the plumes resulting from the OB/OD of some energetics were not as threatening as they appeared, permitting might be possible. As the Department of Defense single manager for conventional ammunition, the U.S. Army Armament, Munitions and Chemical Command (AMCCOM) decided to scientifically pursue technologies leading to identifying and quantifying OB/OD-produced emissions.

PERCEPTION

The prevailing perceptions that OB/OD scientific team faced as the AMCCOM study began were complex. The beliefs that OB/OD operations were inherently dirty and environmentally unacceptable had been spoken so often that they had become unquestionable. Some regulators wondered if DoD was avoiding characterizing OB/OD emissions believing that any such study would confirm that open-air disposal was as bad as suspected. Others felt that predictive models could generate sufficient combustion-product data.

Before the AMCCOM investigation began, faulting the OB/OD detractors was difficult. The manifestations of open-air disposal were both obvious and ominous - loud earth-shaking blasts and dark plumes rising into the sky. Bench tests, usually conducted under unrealistic conditions (e.g., minute amounts of explosive, oxygen-deficient atmosphere), produced data showing large quantities of noxious emissions, thus supporting negative impressions.

DEVELOPING THE BANGBOX™ TESTING SYSTEM

PRELIMINARY TEST (1984-1985)

The concept of capturing a detonation- or burn-produced cloud and analyzing it was so novel that few off-the-shelf technologies and procedures were known to be suitable for the purpose. A preliminary test to identify technology shortfalls was conducted at the Tooele Army Depot. During the course of this test, burns, underground detonations, and surface detonations were conducted using a variety of propellants and exploding ordnance ranging from hand grenades to rockets to general purpose bombs. A UH-1D military helicopter was fitted with instruments and sampling equipment to conduct real-time analyses and collect samples in the plume for subsequent laboratory assay. This test succeeded in pinpointing technology gaps and, in the process, also provided some data on criteria gases.

SYMPOSIUM (1988)

The AMCCOM convened an OB/OD symposium in 1988 to generate ideas on further pursuing OB/OD emissions characterization. Distinguished authorities from around the nation representing disciplines critical to OB/OD testing[a], reviewed all aspects of the preliminary test and recommended instruments, procedures, equipment, target analytes, and venues for follow-on testing[2]. From this group, the AMCCOM test director selected a panel to provide technical advice and oversight. This panel, designated as the technical steering committee (TSC), remains active in continuing development of the testing system and conduct of customer-sponsored testing.

BANG BOX TEST (1989)

A series of small-scale trials was conducted in a small inflatable building operated by Sandia National Laboratories (SNL). Known as the bang box because of its history of being used for testing explosive components of weapons systems, this facility allowed testing of up to 227 g of explosives and 2.27 kg of non-explosive propellants. This test, which included one bulk explosive and two categories of propellant, evaluated recommendations of the OB/OD symposium as selected by the TSC[3]. This test provided the initial inputs into an OB/OD emissions database and screened technologies for advancement into subsequent field testing.

FIELD TESTING (1989-1990)

All field testing was conducted at the U.S. Army Dugway Proving Ground (DPG). Located in the middle of the Great Salt Lake Desert, DPG offered pristine test areas, a highly skilled staff and supporting contractors, and the ability to detonate large amounts of explosives. Three tests each detonated up to 970 kg (2000 lb) of explosives or burned up to 3200 kg (7000 lb)

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[a]Distinguished experts from government, academic, and industrial communities represented analytical chemistry, organic chemistry, chromatography, statistics, environmental law, sampling, meteorology, field testing, propellants and explosives, ammunition and modeling.

of propellant. A Twin Otter fixed-wing aircraft was fitted with the same instruments and equipment as selected by the TSC following the bang box test[b]. Immediately following each detonation, the aircraft made a minimum of three sampling passes through each plume. When the cloud was no long sufficiently stable for good sampling, the aircraft landed and the samples were preserved and shipped to laboratories for assay. Data was collected from four explosives and a variety of propellants[4]

RELATING RESULTS OF BANG BOX AND FIELD TESTS (1991)

At the suggestion of the Atmospheric Research and Exposure Assessment Laboratory (AREAL), U.S. Environmental Protection Agency (USEPA), the scientific team investigated the possible relationship between data produced by bang box and field tests. The subsequent discovery that a relationship existed meant that bang box testing could, for many munitions, replace the need for field testing. This promised time and cost efficiencies without any loss of data quality.

COMPLETION OF ADVANCED FACILITY AT DUGWAY PROVING GROUND (1992)

Dugway Proving Ground installed a new test facility to accommodate more sophisticated testing than had been undertaken in the SNL facility. Although the new facility strongly resembled the original bang box by incorporating an inflatable hemisphere with an attached airlock, it incorporated numerous upgrades. Some enhancements were additional instruments, suppressive and witness shields to allow for the testing of shrapnel-producing munitions, a relief valve to prevent overpressure from damaging the physical structure, and an automatically-regulated air supply to ensure consistent inflation of the chamber. Although formally designated as the Propellant, Explosive, and Pyrotechnic Thermal Treatment Test Evaluation Facility, it is commonly called the BangBox™.

THE OB/OD TESTING SYSTEM

As it has evolved, the OB/OD testing system has four major components. Withdrawal of any component would jeopardize the credibility established during the system's evolution.

FACILITY

The BangBox™ at DPG consists of a 100-m^3 hemisphere fabricated from plasticized fabric and which is kept rigid by a constant injection of fresh air, and a semi-rigid airlock. Within the test chamber are a probe for a PM10 analyzer, three high-volume samplers fitted with quartz-fiber filters during testing, a cylindrical suppressive shield approximately 2.4 x 3.0-m constructed of louvered angle iron, a 1-m^3 steel-lined detonation pit, witness shields constructed of plywood to capture any shrapnel escaping from the suppressive shield, an

[b]The aircraft carried real-time analyzers for criteria gases, a grab bag to permit near-real-time analyses of criteria gases, nephelometers, manifolded quartz-fiber filters to sample semivolatile organic compounds, 6-L SUMMA™ canisters to sample for volatile organic compounds, and a data recorder.

automatically regulated inflation blower, environment-control equipment, and a sampling tube extending into the airlock.

An attached airlock connects to the chamber by doors to admit personnel and allow movement of large equipment into the chamber. Real-time analyzers (CO_2, CO, NO_x, O_3, SO_2, and chlorine) are mounted in racks and electronically connected to a data recorder, also in the airlock. The sampling tube allows the real-time analyzers and evacuated SUMMA™ to sample chamber atmosphere. A heating and air-conditioning system maintains a constant temperature and dust-free environment in the airlock.

TECHNOLOGIES

Key technologies include supercritical fluid chromatography/mass spectrometry which identifies and quantifies semivolatile organic compounds (SVOC) down to the ng level, SUMMA™ canisters that capture chamber atmosphere and the subsequent assay for volatile organic compounds (VOCs) down to the ppt level, the carbon balance method which obviates any need for estimating cloud dimensions when calculating emission factors, and the statistical method of determining emission factors.

QUALITY ASSURANCE/QUALITY CONTROL

From the onset of testing system development, the USEPA has played a major role, both in technical advice and in quality assurance/quality control (QA/QC). The AREAL audited all tests, laboratories, and real-time instruments, spiked air and soil samples, has been on-site for every test conducted, and has written the QA/QC sections of all reports.

PERSONNEL

The expert scientific personnel working on this project are well known and highly respected in their fields. Each has devoted a significant portion of his time to the development and advancement of the system's technologies. Regulators feel comfortable with these individuals and their capabilities, and often solicit information and opinions from them. There have been very few personnel transitions since the program began and this continuity and stability has been a key factor in maintaining program momentum.

REALITY

ENVIRONMENTAL SAFETY

Testing conducted for the three services and accepted by environmental regulators shows that many critical perceptions about OB/OD operations were just that - perceptions. None of the materials tested has produced emissions of concern at levels even approaching USEPA standards. The amounts of dangerous compounds at the source are so low that, when applied to dispersion models and used in risk assessments, are virtually nonexistent and pose no hazards whatsoever to human health or the environment.

DEPARTMENT OF DEFENSE INTEREST AND INVOLVEMENT

Throughout development of the OB/OD testing system, DoD has devoted considerable attention to ensuring its successful completion. The primary concern of DoD has been that the system accurately characterize emissions from open-air destruction of energetic materials and that regulators accept results of the system. The ten years and millions of dollars that have gone into the system's development are clear evidence of DoD's attitude and position.

PREDICTIVE MODELS ARE NOT THE ANSWER

The thermodynamics of detonations and burns are extremely complex and beyond the capability of current models to completely consider. Independent comparisons of model predictions to OB/OD testing system data show great differences. Moreover, models do not predict exotic compounds or metals. Recognizing the accuracy of data from the OB/OD testing system and the inherent difficulties with data from models, many regulators now demand data from the testing system to support permit applications.

CUSTOMER-SPONSORED TESTING

In addition to the AMCCOM-funded bang box and field tests, the OB/OD testing system has responded to needs of the three military services. A test sponsored by the U.S. Air Force Air Combat Command (ACC) involved testing complete munitions and presented some new challenges.

Of the four munitions included in the ACC test, the M18A1 (Claymore) antipersonnel mine was the most interesting. The mine consists of a curved, rectangular, molded case of fiberglass-filled plastic that holds 681 g (1.5 lb) of C4 explosive. Two M6 electric blasting caps are shipped with the mine, but are not installed until just before use. Seven hundred steel pellets are inside the case on the convex (enemy) side of the mine.

Because explosive components of the mine exceeded the 227-g (0.50-lb) NEW limit of the BangBox™ chamber, each mine was disassembled to remove 454 g (l lb) of its explosive charge. As a precautionary measure to protect the fabric wall for ricochets, technicians removed all of the steel pellets. In order to present a worst-case situation, the 360-g (0.79-lb) fiberglass case was not reduced in size. The mine, as adapted for testing, was suspended approximately 30 cm (12 in) above the firing pit floor with the convex and concave sides facing opposite corers of the pit. A single M6 electric blasting cap detonated the mine.

Despite the plastic case being disproportionate to the explosive and the C4 being concentrated in the center of the mine, no detonation produced emissions above USEPA standards. Rather, the emissions were well below the USEPA standard. Tables 1 and 2 present results of M18A1 testing[5].

Table 1. Emission Factors for Volatile Organic Compounds Produced During Open Detonation of M18A1 Antipersonnel Mines.

Sample Number	DU-49&50	DU-51&52	DU-53&54		Standard Deviation
Analyte	(wt/wt)	(wt/wt)	(wt/wt)	Average (wt/wt)	(wt/wt)
Vinylchloride	1.23E-06	NSA[a]	NSA	NA[b]	NA
Methane	5.78E-03	5.88E-03	5.86E-03	5.84E-03	5.12E-05
1,3-Butadiene	3.88E-06	2.43E-06	1.94E-06	2.75E-06	1.01E-06
Benzene	5.45E-04	9.37E-04	9.62E-04	8.15E-04	2.34E-04
Alkanes (Paraffins)	6.46E-05	6.75E-05	8.35E-05	7.19E-05	1.02E-05
Alkenes (Olefins)	1.00E-03	1.35E-03	1.51E-03	1.29E-03	2.62E-04
Aromatics	3.08E-03	2.93E-03	3.16E-03	3.06E-03	1.21E-04
TNMHC	4.65E-03	4.75E-03	5.34E-03	4.91E-03	3.74E-04
TO-12 (NMOC)	5.38E-03	8.10E-03	9.08E-03	7.52E-03	1.92E-03

[a]No sample assay.
[b]Not applicable.

Table 1. Emission Factors for Volatile Organic Compounds Produced During Open Detonation of M18A1 Antipersonnel Mines.

Table 2. Emission Factors for Semivolatile Organic Compounds Produced During Open Detonation of M18A1 Antipersonnel Mines, as Sampled by High-Volume Samplers and Assayed Using Supercritical Fluid Chromatography/Mass Spectrometry.

Sample No.	AF0596468	AF0606569	AF0616670		Standard
	Sample 1	Sample 2	Sample 3	Average	Deviation
Analytes	(wt/wt)	(wt/wt)	(wt/wt)	(wt/wt)	(wt/wt)
2,4-Dinitrotoluene	3.14E-08	5.38E-08	4.37E-08	4.30E-08	1.12E-08
2,4,6-Trinitrotoluene	6.68E-06	2.95E-06	6.99E-06	5.54E-06	2.25E-06
1,3,5-Trinitrobenzene	3.24E-08	BD[a]	5.82E-08	4.53E-08	1.82E-08
Hexahydro-1,3,5-trinitro-1,3,5-triazine[b]	1.03E-05	6.47E-07	1.87E-05	9.87E-06	9.03E-06
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine[c]	3.81E-06	1.38E-06	1.73E-05	7.50E-06	8.59E-06
N-Nitrosodiphenylamine	2.85E-08	2.53E-08	3.03E-08	2.80E-08	2.53E-09
Diphenylamine	2.88E-08	2.23E-08	1.72E-08	2.28E-08	5.82E-09
Pyrene	2.06E-06	1.92E-06	2.13E-06	2.04E-06	1.07E-07
Benz[a]anthracene	BD	8.03E-08	BD	NA[d]	NA
Benzo[a]pyrene	1.77E-07	1.22E-07	6.82E-08	1.22E-07	5.43E-08

[a]Below detection limit.
[b]RDX.
[c]HMX.
[d]Not applicable.

Table 2. Emission Factors for Semivolatile Organic Compounds Produced During Open Detonation of M18A1 Antipersonnel Mines, as Sampled by High-Volume Samplers and Assayed Using Supercritical Fluid Chromatography/Mass Spectrometry.

IMPLICATIONS

ENVIRONMENTAL CONSEQUENCES

Open-air destruction of materials tested will produce no harmful environmental consequences. The levels of all compounds of interest near the source are so low that they are almost negligible; when applied to dispersion models, they are virtually nonexistent. Prior testing during the AMCCOM OB/OD study revealed that the amounts of the compounds deposited in soil are so low that they pose no threat to health or the environment.

DATA ACCEPTABILITY

Because the USEPA was a significant contributor to development of the OB/OD testing system and has audited all tests conducted to date, the data produced by the system enjoys great credibility with the USEPA and many state regulators. Federal and state environmental agencies are demanding this data to support permit applications and are willing to extend temporary permits as long as there is an ongoing good-faith effort to collect this data.

APPLICATIONS

NOTICES OF DEFICIENCY (NOD) and NOTICES OF VIOLATION (NOV)

The military services are using data from all OB/OD testing to respond to NODs and NOVs. As the database grows, these applications will undoubtedly increase.

PERMITTING

The USAF has used OB/OD test data to support permit applications more than the other two services. Installations for which these data are being include Ft Polk (LA), MacDill Air Force Base (AFB) (FL), Avon Park (FL), Minot AFB (FL) Ellsworth AFB (SD), Cannon AFB (NM), Melrose Range (NM), Barksdale AFB (LA), China Lake Naval Weapons Station (CA) and Edwards AFB (CA). Additional users include Lawrence Livermore Laboratory (CA) and an unidentified commercial firm (CA). None has received a permit, but all applications are moving forward and no regulator has expressed any displeasure with the data or the means by which it was obtained.

RISK ASSESSMENTS

The OB/OD data, by its very nature, is ideal to use in risk assessments. The Massachusetts National Guard (MNG), responding to concerns of communities adjacent to Camp Edwards, sponsored a BangBox™ test of artillery propellants under specified climatic conditions. In order to maintain credibility, the MNG is waiting for risk assessment protocols to be finalized by the Commonwealth of Massachusetts before releasing these data.

TRAINING AREAS

Regulators are moving toward requiring emissions data for training activities that include use of energetic munitions. A planned underground BangBox™ will permit testing of items such as artillery projectiles under simulated employment conditions including subsurface detonation.

PUBLIC RELATIONS and LITIGATION

Until the advent of OB/OD testing, installation public information officers had no scientific evidence to use while formulating responses to citizen queries and criticisms of OB/OD disposal operations. Although the data is scientific, it is easily translatable into language the lay person can understand.

In our litigious society, accurate and unbiased data can well serve attorneys defending the government or commercial OB/OD site operators. Expanded databases encompassing many energetic materials will be able to rapidly respond to needs of the defense.

LOOKING TO THE FUTURE

The present BangBox™ cannot accommodate soil or detonations larger than 227 g (0.5 lb). We anticipate that future permitting needs will include munitions with a NEW exceeding this limit and for inclusions of soil, possibly site-specific soil. The laboratory assays for SVOC are accurate, but a large number of assays is admittedly expensive and time-consuming. Improvements in facility and technologies can overcome these problems.

EXPANDED FACILITIES

Under Strategic Environmental Research and Development Program sponsorship, the OB/OD testing program will install three new BangBoxes™ so that all conventional propellants and explosives in the demilitarization inventory can be tested. The first will be similar to the existing BangBox™ at DPG, but incorporating an improved air-circulation system and deleting the suppressive shield system. This facility will expeditiously test neat explosives and propellants.

The second new BangBox™ will be a rigid-frame facility approximately 15,000 m^3. This will be a low-cost means of testing munitions with higher NEWs.

The third new BangBox™ will consist of an underground chamber capable of testing large munitions such as artillery projectiles, buried detonations, and detonations including site-specific soils.

NEW TECHNOLOGIES

Due to the magnitude of anticipated testing requirements, the program needs new technologies that can speed the testing and assay processes. Candidate instruments include the atmospheric-pressure time-of-flight mass spectrometer, Fourier transform infrared, and across-the-stack monitors. As new real-time analyzers are developed for criteria gases and chlorine, the test director and TSC will investigate them for possible inclusion into the instrument package.

TESTING OF MORE DIFFICULT MATERIALS

The demilitarization community views open-air disposal of pyrotechnics as creating a bigger environmental problem than do propellants or explosives. However, emissions from pyrotechnics have not been characterized under real-world conditions. This is a natural mission for BangBoxes™.

Open burning of ammonium perchlorate (AP) propellants, like pyrotechnics, is widely viewed as being environmentally unacceptable. While characterization of AP propellant emissions has not yet been undertaken, the BangBox™ is capable of such testing. As part of this effort, the BangBox™ technical staff is now developing a chlorine balance method.

COMMERCIAL APPLICATIONS

Commercial manufacturers of energetic materials face the same permitting and public relations problems as does DoD. Because there is no facility anywhere with capabilities and acceptance of the DPG BangBox™ system, they will be turning to the DPG BangBox™ program for assistance.

THE BOTTOM LINE

REGULATORS

The environmental community accepts BangBox™ results as accurate. No other testing system, anywhere, enjoys this status. While the OB/OD testing system can characterize VOC emissions down to the ppt level, SVOCs to the ng level, and report all metals, models are unable to predict the full range of exotic compounds and metals. Many regulators now are rejecting model-generated data and demanding data from the OB/OD testing system.

SAVINGS

Besides identifying which energetics are environmentally suited for OB/OD operations, the OB/OD testing system can identify which munitions require alternate methods, thus permitting a focussing of R&D efforts on the greatest need.

RETAINING THE MERITS OF OB/OD DISPOSAL OPERATIONS

The benefits of OB/OD disposal operations cannot be overstated. They have the highest thru-put of any disposal procedure for energetic materials, are the least expensive, are the best understood, and enjoy a safety record unparalleled by any other disposal system. They are the only way of keeping ahead of the flood of unwanted munitions being generated by force reductions and base closures.

ENVIRONMENTAL SUITABILITY

Results show that OB/OD is a viable and effective means of destroying many unwanted conventional energetic materials. The high temperatures of detonation and burn fireballs (which incinerators or furnaces cannot achieve), destroy all dangerous compounds generated at the instant of explosion detonation and propellant ignition.

Open burning and open detonation disposal procedures are environmentally suited for many or most conventional energetic munitions. These thermal treatments are alive and well, and should not be misunderstood or ignored.

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